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Gentlemen:

Introduction

This report covers the work done during the last quarter on the Performance and Design Study of Plenum Chamber Combustion for V/STOL aircraft. The work included in this report was accomplished from 15 February to 15 May 1965. This work was performed for the National Aeronautics and Space Administration under amendment 1, dated 22 March 1965, of the Defense Purchase Request No. R-121 of 14 February 1964.

Results and Discussion

I. Right Angle Combustor

A. General

1. During the time interval reported, the sea level performance of the right angle combustor, enclosure (1), and two minor variations thereof was determined. The performance for each of these burners was determined for the following conditions:

Inlet Total pressure	=	60 in. hg abs
Inlet Total temperature	=	240°F
Reference Velocity	=	100, 150, 180, 200, and 220 ft/sec

(The reference velocity is based on mass rate of flow, burner inlet pressure and temperature and on the maximum cross-section area)

2. At the above conditions, the performance of the combustor was determined for:

a. Both fuel nozzles supplying an equal quantity of fuel.

b. The combustor operated as a "straight through combustor".

c. The combustor operated as a "reverse flow combustor".

The above tests amounted to approximately five hundred data points.

3. The three right angle combustor configurations tested were designated: RAC-1, RAC-1A, and RAC-1B. The difference between these configurations was in the size of the swirl slot area in the straight through portion. Table I lists the swirl slot area for each of the configurations.

TABLE I

Burner Designation	No. of Swirl Slots	Area Per Swirl Slot Sq. In.	Total Swirl Slot Area Sq. In.	% Slot Area Increase From RAC-1
RAC-1	12	.0585	.7020	0
RAC-1A	12	.1110	1.3320	89.7
RAC-1B	12	.1386	1.6632	136.9

B. Cold Flow Tests

4. The cold flow pressure drop decreased as the size of the swirl slots was increased (i.e. the pressure drop of the burners decreased as follows: RAC-1> RAC-1A> RAC-1B). Pressure drop data of the RAC-1 and RAC-1B burners are shown on enclosures (3), (4), and (5). Enclosure (3) is an arithmetic plot of pressure drop characteristics versus reference velocity whereas enclosures (4) and (5) are log-log plots of the same variables. The log-log plots served the following purposes:

a. Verification of the exponential relationship between percent pressure drop and reference velocity.

b. Experimental determination of the exponent (approximately 2).

c. Indication of any faulty data points.

5. The loss in pressure due to turning the airflow is shown on enclosure (3). This pressure loss was determined with the inner combustor liner removed. The plot indicates that at a reference velocity of 200 ft/sec a pressure loss of approximately 2.55% would be incurred.

C. Hot Flow Tests

6. For each series of tests, the combustor was operated over a range of fuel flows. These fuel flows provided ΔTs from a minimum of 250°F up to a maximum of 2250°F. Tests were terminated when blowout occurred or at least one thermocouple indicated a temperature of 2500°F.

7. None of the right angle combustors tested, for all modes of operation, and at any operating conditions, had a lean blowout.

8. When operating with both fuel nozzles flowing equal amounts of fuel, none of the combustors had a rich blowout at any of the velocities tested.

9. At a reference velocity of 100 ft/sec no rich blowout occurred for either the straight through or reverse flow mode of operation.

10. At reference velocities of 150, 180, 200, and 220 ft/sec rich blowouts occurred for both the straight through and the reverse flow modes of operation. Also, as expected, rich blowout occurred for the reverse flow mode at lower fuel/air ratios than for the straight through mode of operation.

11. Neither the combustion efficiency nor the stability limits were significantly affected by the changes in swirl slot area. However, these changes did alter the carbon formation tendencies of the straight through portion. The carbon formation decreased with increasing swirl slot area.

12. The combustion efficiency of the RAC-1 combustor is shown on enclosure (6) plotted versus reference velocity. This enclosure was drawn for each mode of operation (i.e. straight through, reverse flow, and both fuel nozzles) at a fuel/air ratio of .015. This plot indicates that methods of improving the efficiency of the straight through portion of the combustor should be investigated. The investigation being conducted in the straight through burner rig will provide applicable data for this problem.

II. Straight Through Combustors

A. A straight through combustor facility was designed and installed in test cell 1E. This equipment has greater capacity and flexibility than the 9W rig formerly used. Tests will be made in the straight through rig to continue the investigative work initialed during the first year of the program. The first burner to be tested has been designed and fabricated. This configuration will provide additional data on the relationship between inner to outer liner area ratio and combustor performance.

III. Aerodynamic Combustor

A. The requirements of a high pressure air stabilized combustor have been studied and preliminary design work has been carried out. The initial aerodynamic combustor will be a segmented, hexagonal wing injecting high pressure air radially inward. The cross-section of the wing conform to an NACA 0024 airfoil.

IV. Future Plans

A. A work versus time schedule was prepared for the time interval from the 15 April 1965 to 15 February 1966. This schedule, shown on enclosure (2), consists of the following work:

1. The altitude performance (Mach No. 1.2 at 45,000 ft) of the RAC-1 class of burners will be ascertained in test cell 9W.

2. Additional studies into the requirements for efficient combustion at the environmental conditions imposed by the fan burner will be made. This work will be performed in the straight through burner located in test cell 1E.

3. Based on the performance of the RAC-1 class of burners and on the straight through burners, a second class of right angle combustors, RAC-2, will be designed and evaluated at altitude and sea level. The objective of the redesign will be to increase the combustion efficiency and space heat release rate and to decrease the pressure drop of the RAC-1 class of burners.

4. The potential of high pressure, air stabilized combustion will be investigated. This type of combustor will be classed as an aerodynamic combustor or "aerodynamic flameholder". The design and fabrication will be completed in the next quarter. Testing of the aerodynamic combustor will be initiated during the next quarter.

B. No test work is scheduled for the time period from 15 December 1965 to 15 February 1966. This time period will be used for testing in those areas which prior tests indicate should be investigated and for preparing the final report.

Very truly yours,

J. R. Pichtelberger

J. R. PICHTELBERGER
Supt., Fuels & Lubricants Division
Aeronautical Engine Laboratory
By direction of the Commanding Officer

Enclosures:
(1) Schematic of Right Angle Combustor
(2) NASA Plenum Combustion Chamber Test Schedule
(3) Combustor Pressure Drop as a Fraction of the Inlet Total Pressure Versus Reference Velocity - Cold Flow (RAC-1 and RAC-1B Combustors - Arithmetic Plot)
(4) Combustor Pressure Drop as a Percentage of the Inlet Total Pressure Versus Reference Velocity - Cold Flow (RAC-1 Combustor - Logarithmic Plot)
(5) Combustor Pressure Drop as a Percentage of the Inlet Total Pressure Versus Reference Velocity - Cold Flow (RAC-1B Combustor - Logarithmic Plot)
(6) Combustion Efficiency Versus Reference Velocity for the RAC-1

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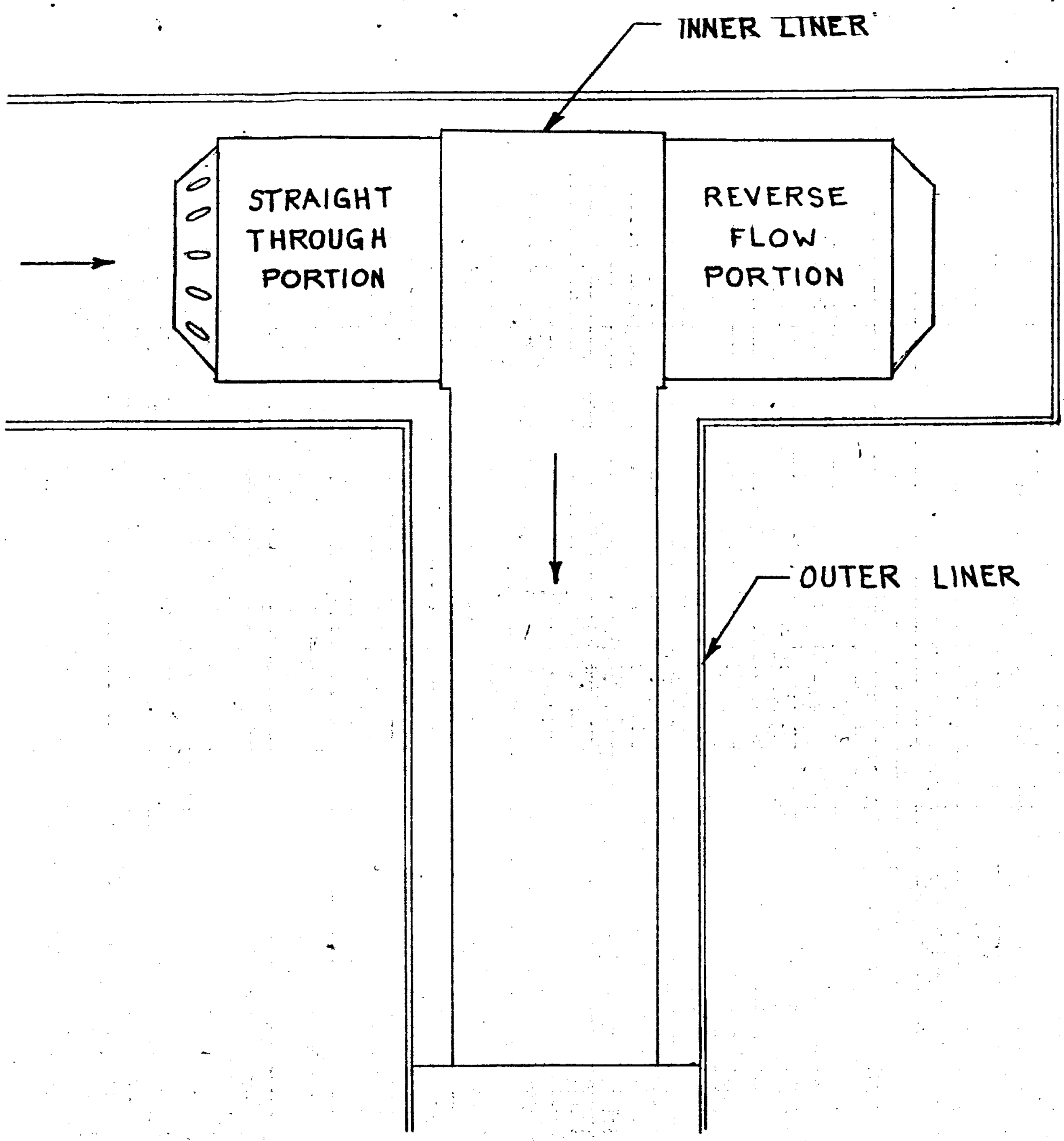
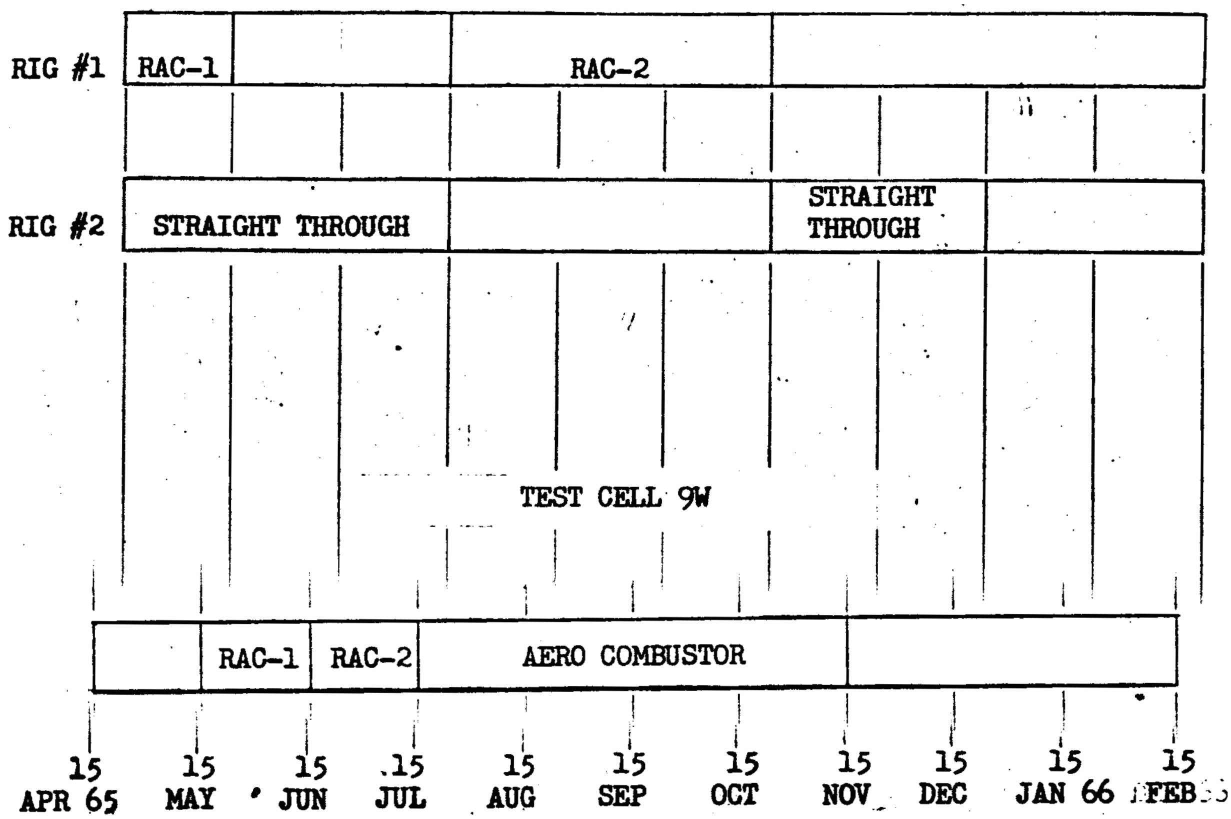


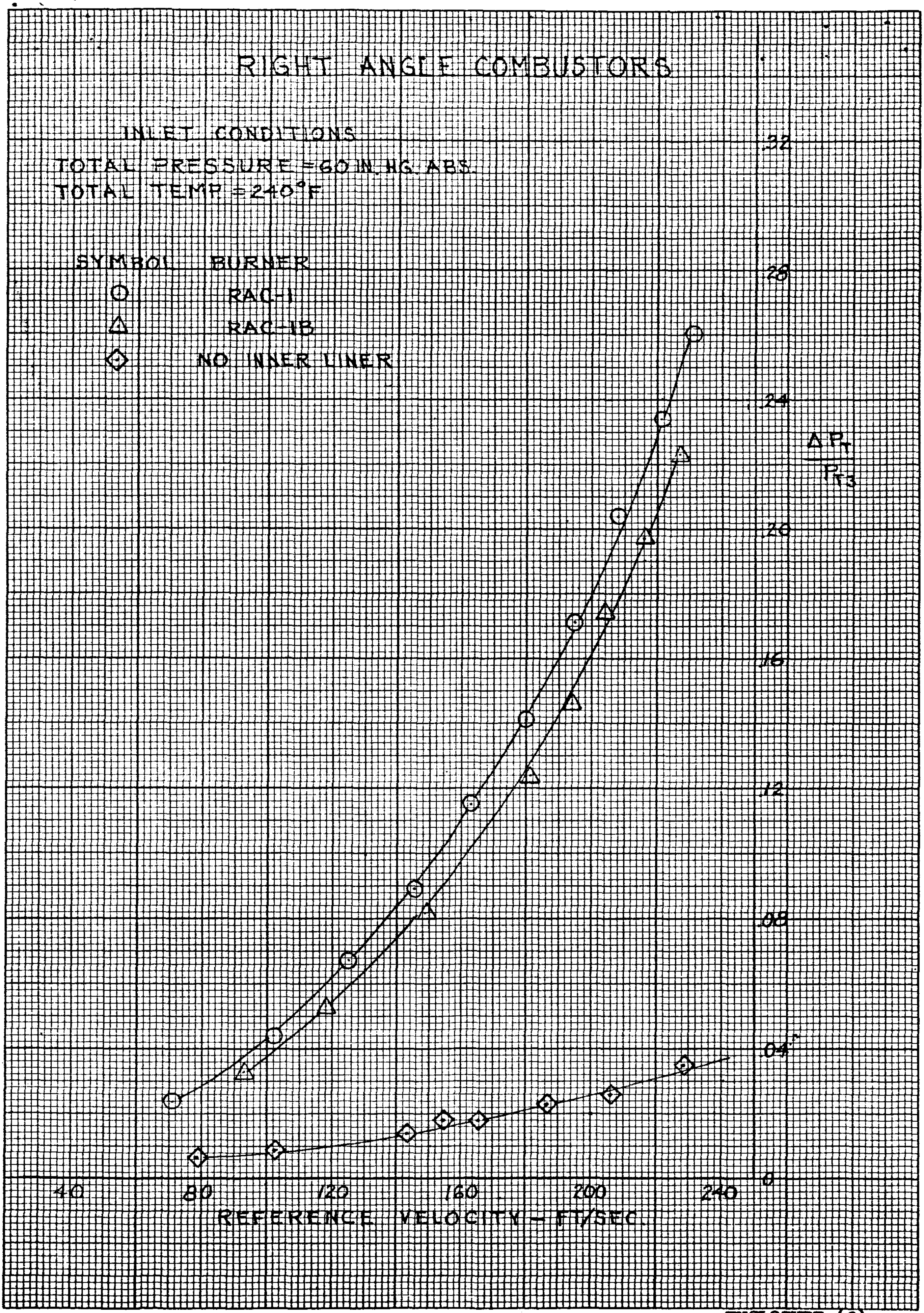
SCHEMATIC OF RIGHT ANGLE COMBUSTOR

NASA PLENUM COMBUSTION CHAMBER SCHEDULE

TEST CELL 1E



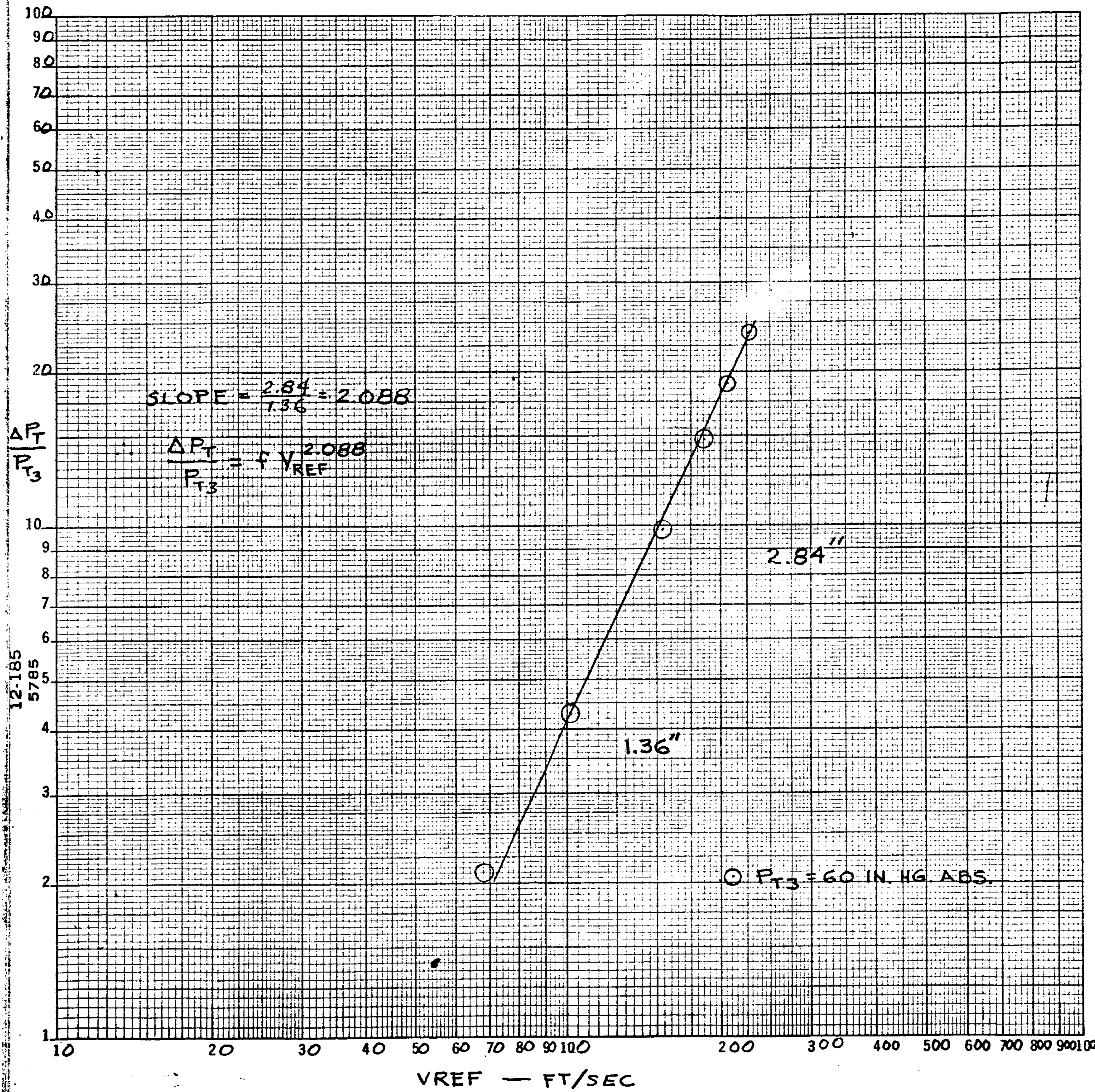
ENCLOSURE (2)


RIGHT ANGLE COMBUSTORS
INLET CONDITIONS
TOTAL PRESSURE = 60 IN. HG. ABS.
TOTAL TEMP. = 240°F
SYMBOL BURNER
RAC-1
RAC-1B
NO INNER LINER
32
28
24
20
16
12
.08
.04
0
$\frac{\Delta P_T}{P_{T3}}$
40
80
120
160
200
240
REFERENCE VELOCITY - FT/SEC.

ENCLOSURE (3)

BURNER NO. RAC-1

COLD FLOW-INLET CONDITIONS
TOTAL PRESSURE = 60 IN. HG. ABS.
TOTAL TEMP = 240°F

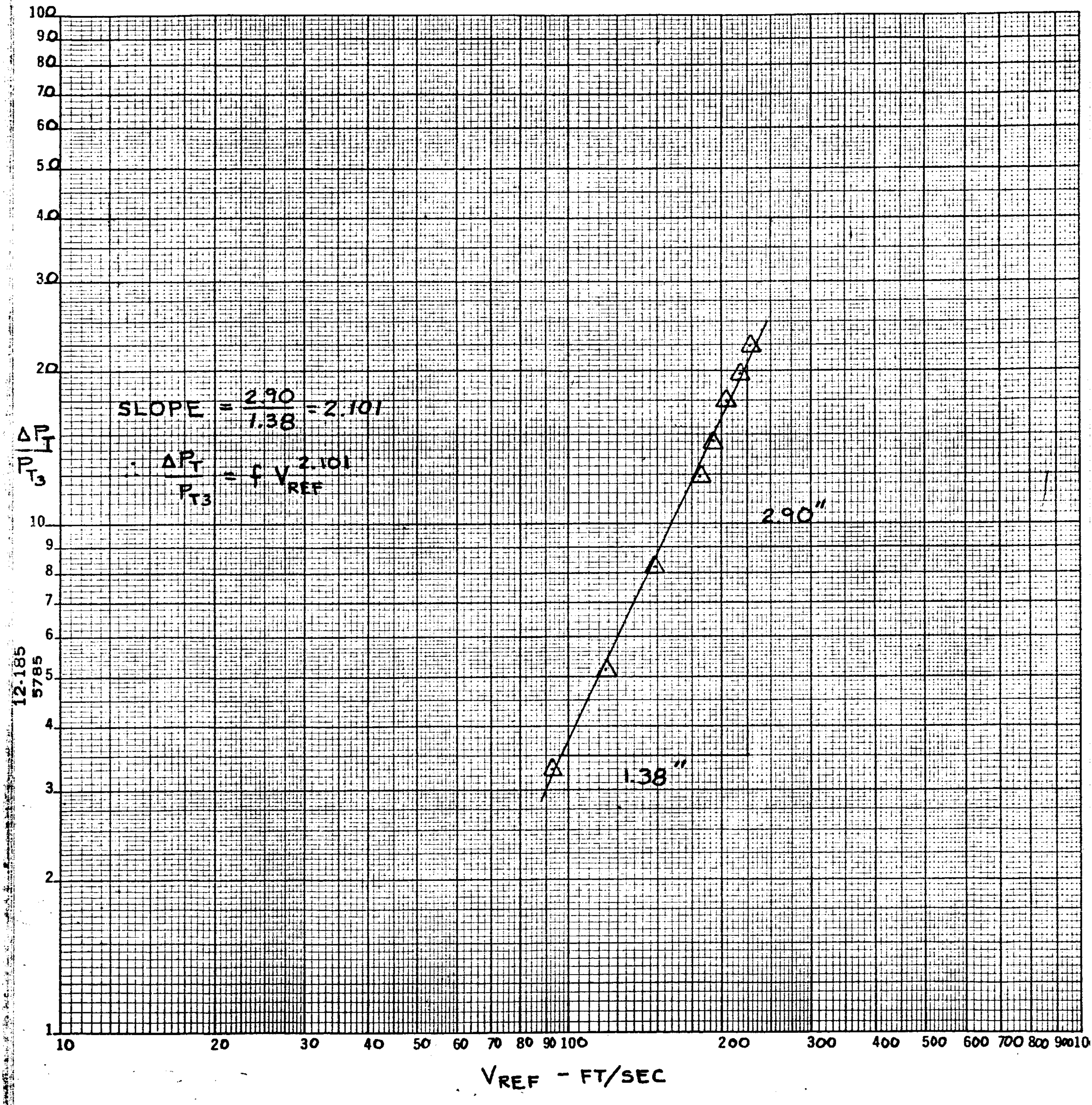


ENCLOSURE (4)

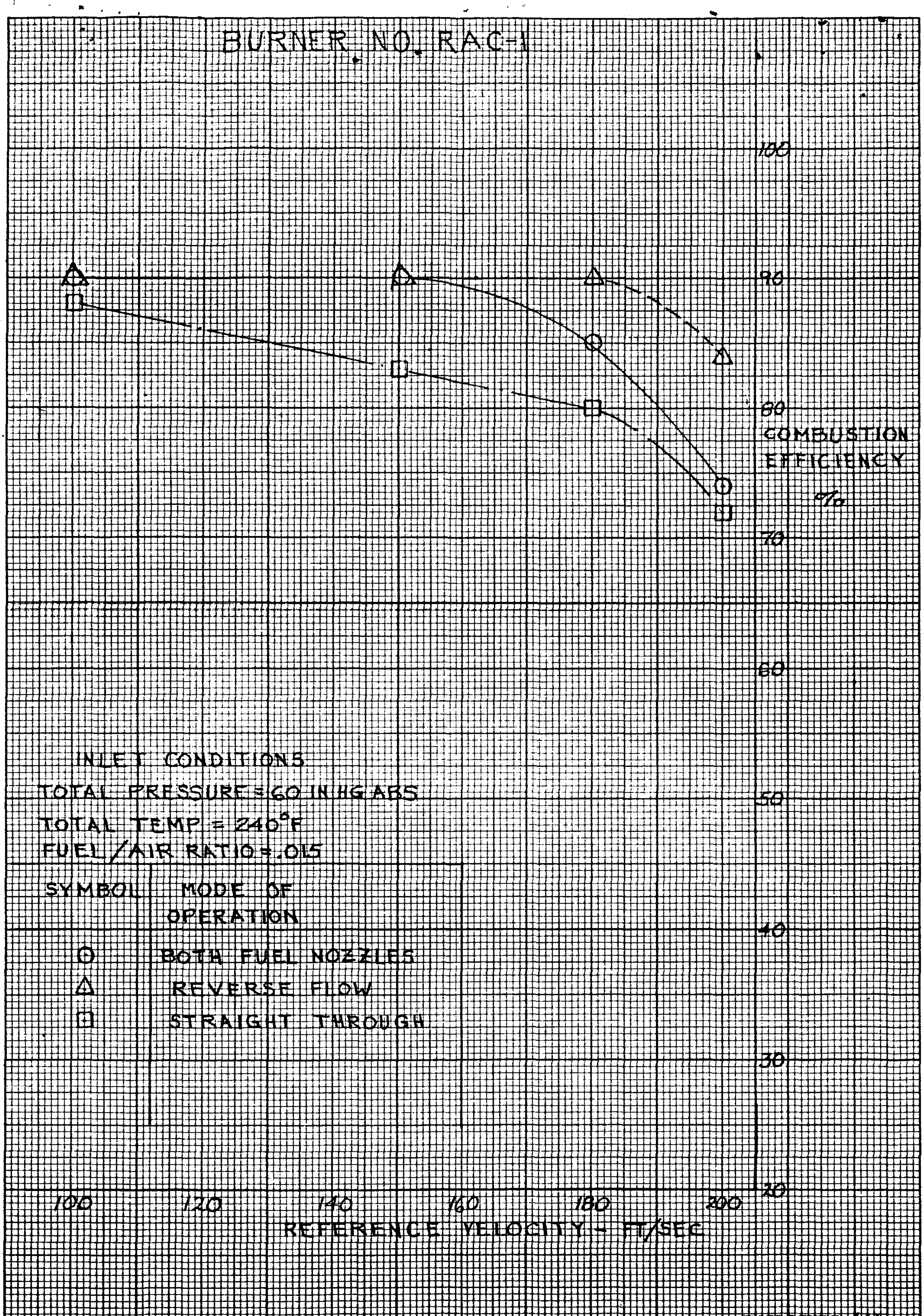
BURNER NO. RAC-1B

COLD FLOW–INLET CONDITIONS

TOTAL PRESSURE = 60 IN. HG. ABS.
TOTAL TEMP = 240°F



ENCLOSURE (5)


BURNER NO. RAC-1
100
90
80
70
60
50
40
30
20
COMBUSTION
EFFICIENCY
%
INLET CONDITIONS
TOTAL PRESSURE = 60 IN HG ABS
TOTAL TEMP = 240°F
FUEL/AIR RATIO = .015
SYMBOL
MODE OF
OPERATION
○
BOTH FUEL NOZZLES
△
REVERSE FLOW
□
STRAIGHT THROUGH
100
120
140
160
180
200
REFERENCE VELOCITY - FT/SEC

ENCLOSURE (6)